



## Turn on the lights: Macroeconomic factors affecting renewable energy in Pakistan



Ihtisham Abdul Malik <sup>a,\*</sup>, Ghamz-e-Ali Siyal <sup>b</sup>, Alias Bin Abdullah <sup>a</sup>, Arif Alam <sup>c</sup>,  
Khalid Zaman <sup>b,1</sup>, Phouphet Kyophilavong <sup>d</sup>, Muhammad Shahbaz <sup>e</sup>, Siraj Ullah Baloch <sup>b</sup>,  
Tauqeer Shams <sup>b</sup>

<sup>a</sup> Faculty of Arts and Social Sciences, Department of East Asian Studies, University of Malaya, Malaysia

<sup>b</sup> Department of Management Sciences, COMSATS Institute of Information Technology, Abbottabad, Pakistan

<sup>c</sup> Department of Development Studies, COMSATS Institute of Information Technology, Abbottabad, Pakistan

<sup>d</sup> Faculty of Economics and Business Management, National University of Laos, POBOX7322, NUoL, Vientiane, Laos

<sup>e</sup> Department of Management Sciences, COMSATS Institute of Information Technology, Lahore, Pakistan

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### ABSTRACT

The objective of the study is to examine the relationship between macroeconomic factors (i.e., population growth; urbanization, industrialization, exchange rate, price level, food production index and live stock production index) and renewable energy in Pakistan over a period of 1975–2012. In addition, this study uses oil rent as an intervening variable to overcome the biasness of the single equation model. The results indicate that macroeconomic factors positively contributed to renewable energy consumption in Pakistan. The causality test indicate that there is a unidirectional causality running towards macroeconomic factors to renewable energy in Pakistan, however, renewable energy Granger cause oil rent but not via other route. In addition, there is bidirectional causality between exchange rate and live stock production in Pakistan. Variance decomposition analysis shows that economic growth has a major contribution to increase renewable energy in Pakistan.

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## 1. Introduction

Pakistan is facing one of its worst energy crises, and with the population growth, demand for electricity is set to increase exponentially. According to the National Transmission and Distribution

Company (NTDC), annual electricity growth rate is estimated to hover around 5–6% over the next ten years, which translates to peak electricity demand of 32,000 MW by 2020 [41]. In Pakistan, potential for almost all types of renewable energies exists in the country. These types include solar (PV and thermal), wind, biogas, microhydel/canal fall, biodiesel production, biomass waste to energy production, geothermal, tidal/ocean energies, etc [39].

In the generation of electricity from renewable sources, the Asian and Pacific region led the world in 2010. But this amounted to only 15.8% of the region's total electricity, which is below the world average of 19.4%. With less than 400 kWh per capita, the annual household electricity consumption in the region is the

\* Corresponding author. Tel.: + 92 313 5937627; fax: +92 992 383441.

E-mail addresses: [ihtisham@ciit.net.pk](mailto:ihtisham@ciit.net.pk) (I.A. Malik),

[khalidzaman@ciit.net.pk](mailto:khalidzaman@ciit.net.pk) (K. Zaman),

[Phouphetkyophilavong@gmail.com](mailto:Phouphetkyophilavong@gmail.com) (P. Kyophilavong),

[Sirajbaloch903@yahoo.com](mailto:Sirajbaloch903@yahoo.com) (S.U. Baloch).

<sup>1</sup> Tel.: +92 334 8982744; fax: +92 992 383441.

second lowest among the world's regions, after Africa where it is 200 kWh [40]. Renewable energy market is an emerging market in Pakistan. Solar opportunities exist in Punjab province, wind opportunities exist in Sindh and Baluchistan provinces, coal opportunities exist in all provinces, hydro opportunities exist in North of Pakistan and bio-energy exists in all provinces [7]. Government of Pakistan is putting greater emphasis on Renewable Energy and has set a target of 10% renewable energy or 2700 MW in the Country's energy mix by 2015 [30].

The purpose of the study is to evaluate the impact of macro-economic factors on renewable energy in Pakistan. The number of literature available on the said topic, however, the major contribution of the study is to include oil rent as an intervening variable which overcome the biasness of the single equation. Pao and Fu [28] examine the relationship between different types of energy consumption (i.e., renewable energy, non-renewable energy, non-hydroelectric renewable and primary energy consumptions) and economic growth in Brazil, over a period of 1980–2010. The results reveal that there is a positive relationship between non-hydroelectric renewable energy consumption and economic growth in one hand, while on the other hand, total renewable energy consumption also have a significant impact on real GDP. Ocal and Aslan [24] examine the causal relationship between economic growth and renewable energy in the context of Turkey. The results show that causality running between economic growth to renewable energy but not vice versa. Bakhtyar et al. [6] presented an archival–statistical overview of the renewable energy production in Philippines, Thailand, Malaysia, Indonesia, and Singapore. The results conclude that over a period of time, the share of renewable energy in energy production in these countries tend to decline and more reliance is placed on fossil fuels for energy production. Menegaki [22] examines the growth–renewable energy nexus in the panel of European countries by using data envelopment techniques. The results show mean overall efficiency is equal to 0.892, while mean pure technical efficiency is 0.569 and scale efficiency 1.798. Countries with remarkable renewable energy performance have medium to low efficiency, while renewable energy laggards are among the most technically efficient countries in Europe. Lin et al. [19] investigate causality between sectoral renewable energy consumption and economic growth for the US data from 1989 to 2008. The results show that the feedback relationship between industrial renewable energy and economic growth, while neutrality hypothesis holds for the rest of the sectoral energy consumptions.

Mudakkar et al. [20] examine the relationship between energy determinants and growth factors in Pakistan over a period of 1975–2011. The results indicate that there is a unidirectional causality running from energy factors to growth, however, there is a feedback relationship between electric power consumption to population density in Pakistan. Al-mulali et al. [2] examine the relationship between renewable energy consumption and GDP growth in high income, upper middle income, lower middle income, and high income countries. The results show that around 79% of the countries have a feedback relationship between economic growth and renewable energy consumption, while, in 19% cases, there is no causal relationship between the variables. In another study of Al-mulali et al. [3], the study examines the impact of renewable and non-renewable energy consumptions on economic growth in 18 Latin American countries, over a period of 1980–2010. The results conclude that renewable and non-renewable energies act as a significant contributor to increase economic growth both in the short and long-run.

Zhang et al. [44] analyze the interaction between renewable energy policy and renewable energy industrial policy. In addition, China's wind and solar PV sector has been analyzed during 2005–2012. The study emphasizes the need of interaction between renewable energy policy and renewable energy industrial policy.

Apergis and Payne [4] determine the Granger-causal relationship between renewable, non-renewable electricity consumption and economic growth for South America. The results indicate bidirectional causality between renewable and non-renewable electricity consumption, respectively and economic growth in both the short-run and long-run. Saboori and Sulaiman [32] examine the relationship between economic growth, CO<sub>2</sub> emissions, and energy consumption in Malaysia for the period 1980–2009. The results support an inverted U-shaped relationship. The Granger causality test shows the feedback relationship between economic growth and CO<sub>2</sub> emissions.

Shahbaz et al. [38] examine the environmental Kuznets hypothesis in Pakistan by using the time series data from 1971 to 2009. The results supported the environmental Kuznets hypothesis in Pakistan. In another study by Shahbaz and Lean [35], the study examines the relationship between energy consumption and financial development in the light of urbanization and industrialization of Tunisia, over a period of 1971–2008. The results confirm the feedback hypothesis among different variables i.e., financial development and energy consumption, financial development and industrialization, and industrialization and energy consumption. Satti et al. [33] examine the causal relationship between coal consumption and economic growth in the context of Pakistan, over a period of 1974–2010. The results show that there has bidirectional causality between economic growth and coal consumption. Khan et al. [18] examine the causal relationship between greenhouse gas emissions, economic growth and energy consumption in Pakistan between 1975 and 2011. The results suggest that energy consumption acts as an important driver for increase in greenhouse gas emissions in Pakistan. In addition, causality runs from energy consumption to greenhouse gas emissions but not vice versa. Farooqui [12] reviews various renewable energy sources, including hydel, solar, wind and biomass, and their current and future penetration prospects in the total energy mix. The results concluded that Pakistan has the feasible potential of 30 GW of installed power capacity from hydel and 50 GW of installed capacity from wind by 2030. According to Khalil and Zaidi [17, p. 194],

“Energy is the basic need of modern life. Pakistan is an energy deficient country. Energy crisis is making bad impacts and destroying the economy”.

Ozturk and Salah Uddin [27] investigate the causal relationship between carbon emissions, energy consumption and economic growth in India, over a period of 1971–2007. The results show the bidirectional causality between economic growth and energy consumption in India. Shahbaz et al. [36] investigate the causal relationship between the natural gas consumption and economic growth in Pakistan. The study finds the natural gas consumption-led-growth hypothesis in Pakistan. In the similar line, Shahbaz et al. [37] further examined the casual energy consumption, carbon emissions, globalization and Turkish economic growth, over a period of 1970–2010. The results confirm the environmental Kuznets curve in Turkish economy. Acaravci and Ozturk [1] investigate the causal relationship between energy consumption, carbon emissions and economic growth in nineteen European countries. The results found a positive long-run elasticity estimate of emissions with respect to energy consumption in Denmark, Germany, Greece, Italy and Portugal. Shahbaz et al. [34] examine the validity of environmental Kuznets curve (EKC) in case of Tunisia, for the period of 1971–2010. The results validate the existence of EKC in Tunisia. Ozturk and Acaravci [26] examine the long-run relationship between economic growth, carbon emissions, energy consumption and employment ratio in Turkey, over the period 1968–2005. The results support the neutrality hypothesis between carbon emissions and economic growth in one hand, while on the other hand, energy consumption also does not

Granger cause real GDP per capita in case of Turkey. Kessides [16] examines the problems confronting Pakistan's electricity sector and identifies the key elements of a potential policy response to address the country's severe power crisis. According to Awan et al. [5, p. 236],

“The main reason for the energy crisis is rapidly increasing the prices of hydro-carbon resources and lack of planning to foresee the increasing energy demand in the country.”

The above studies show the strong correlations between economic factors and renewable energy. In the subsequent section, an action has been made to find the empirical relationship between macroeconomic factors and renewable energy in the context of Pakistan. The objective of the study is to analyze the trade-off between renewable energy and economic factors in Pakistan. The more specific objectives are the following:

- i. To find the long-run relationships between renewable energy and economic factors.
- ii. To examine the causality between renewable energy and economic factors in the context of Pakistan.

The study is divided into the following sections: after introduction which is presented in Section 1 above, Section 2 shows data source and methodology. Results are discussed in Section 3. Final section concludes the study.

## 2. Data source and methodological framework

The annual time series data is employed for the Pakistan's economy over a period of 1975–2012. All relevant data is taken from *World development indicators* published by World Bank [43] and Economic surveys of Pakistan (various issues). Energy related indicators such as oil consumption i.e., oil rent and combustible renewable energy and waste are used to shed light on the possible impact of macroeconomic factors such as population, urbanization, industrialization, exchange rate, inflation, food production index and live stock production index in Pakistan. All these variables are expressed in natural logarithm and hence their first differences approximate their growth rates.

In this study, the focus is on the relationship between combustible renewable and waste in percentage of energy and

macroeconomic factors like petroleum consumption i.e. oil rent in US \$ million; population rate in the percentage growth; urbanization represents urban population growth rate, industrialization shows industry value added; exchange rate in US \$; inflation in percentage; food price index and live stock production index has been evaluated in the context of Pakistan. These variables are selected because of their vital importance to an emerging economy like Pakistan.

Fig. 1 highlights in schematic fashion the methodological approach adopted in the paper. According to this framework, renewable energy has been checked on GDP through macroeconomic indicators with intervening variable that is oil rent.

The study used multiple equations for assessing the relationship between macroeconomic factors and renewable energy by intervening oil rent as a variable in the model. This is unlikely in time series analysis to take all variables in the single equation due to less data availability. Therefore, the following seven equations (Panels A–G) are used to assess the impact of macroeconomic factors on renewable energy in Pakistan, i.e.

$$\text{Panel A : } \ln(\text{RE})_t = \beta_0 + \beta_1 \ln(\text{POP}) + \beta_2 \ln(\text{OILR}) + \mu \quad (1)$$

$$\text{Panel B : } \ln(\text{RE})_t = \beta_0 + \beta_1 \ln(\text{URBAN}) + \beta_2 \ln(\text{OILR}) + \mu \quad (2)$$

$$\text{Panel C : } \ln(\text{RE})_t = \beta_0 + \beta_1 \ln(\text{IND}) + \beta_2 \ln(\text{OILR}) + \mu \quad (3)$$

$$\text{Panel D : } \ln(\text{RE})_t = \beta_0 + \beta_1 \ln(\text{EXR}) + \beta_2 \ln(\text{OILR}) + \mu \quad (4)$$

$$\text{Panel E : } \ln(\text{RE})_t = \beta_0 + \beta_1 \ln(\text{INF}) + \beta_2 \ln(\text{OILR}) + \mu \quad (5)$$

$$\text{Panel F : } \ln(\text{RE})_t = \beta_0 + \beta_1 \ln(\text{FPI}) + \beta_2 \ln(\text{OILR}) + \mu \quad (6)$$

$$\text{Panel G : } \ln(\text{RE})_t = \beta_0 + \beta_1 \ln(\text{LSPI}) + \beta_2 \ln(\text{OILR}) + \mu \quad (7)$$

where RE represents combustible renewable and waste; POP represents population growth; FPI represents food production index; URBAN represents urbanization i.e. urban population growth (% of GDP); INDUS represents industrialization i.e. industry, value added; OILR represents oil rent (% of GDP); EXR represents official exchange rate; INF represents inflation (consumer price index) and GDPG is the GDP growth rate. All the variables seen in Table 1 are expected to have positive impact on renewable energy.

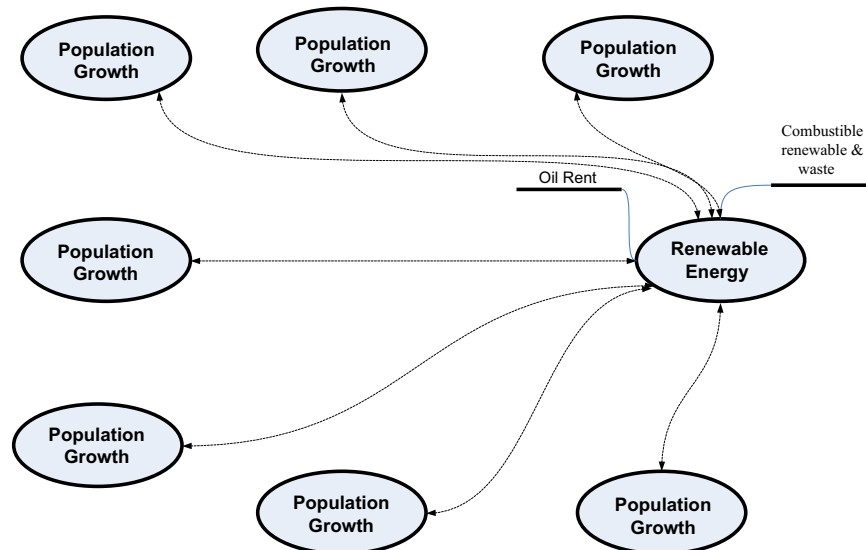


Fig. 1. Research framework.  
Source: Self Extract.

**Table 1**  
Variables in the equations and expected signs.

| Variables                    | Measurement  | Expected signs | Data source     |
|------------------------------|--|----------------|-----------------|
| RE                           | Combustible renewable and wastes as percentage of total energy |                | World Bank [43] |
| <b>Intervening variable</b>  |  |                |                 |
| OILR                         | Oil rent in US \$ million                                      | Positive       | World Bank [43] |
| <b>Macroeconomic factors</b> |  |                |                 |
| FPI                          | Food production index  | Positive       | World Bank [43] |
| POP                          | Population, % growth   | Positive       | World Bank [43] |
| URBAN                        | Urbanization, % growth   | Positive       | World Bank [43] |
| INF                          | Inflation, consumer production index, %                        | Positive       | World Bank [43] |
| LSTOCK                       | Livestock production (1999–2001 = 100)                         | Positive       | World Bank [43] |
| IND                          | Industry, value added (% of GDP)                               | Positive       | World Bank [43] |
| EXR                          | Official exchange rate in US \$                                | Positive       | World Bank [43] |
| GDP                          | Gross domestic product rate                                    | Positive       | World Bank [43] |

### 2.1. Econometric framework of the study

The test for co-integration consists of two steps: first, the individual series are tested for a common order of integration. If the series are integrated and are of the same order, it implies co-integration.<sup>2</sup> Second, Dickey and Fuller [9] devised a procedure to formally test for non-stationary. The Augmented Dickey Fuller (ADF) test is used to test the stationarity of the series. The ADF test is a standard unit root test; it analyzes the order of integration of the data series [10]. These statistics are calculated with a constant, and a constant plus time trend, and these tests have a null hypothesis of non-stationary against an alternative of stationary.

Johansen's cointegration tests applied on the series of same order of integration i.e.,  $I(1)$  series which determine the long run relationship between the variables. When series are cointegrated of order 1, trace test (Johansen's Approach) indicates a unique cointegrating vector of order 1 and hence indicates the long run relationship. In the multivariate case, if the  $I(1)$  variables are linked by more than one co-integrating vector, the Engle and Granger [11] procedure is not applicable. The test for co-integration used here is the likelihood ratio put forward by Johansen and Juselius [14], indicating that the maximum likelihood method is more appropriate in a multivariate system. Therefore, this study has used this method to identify the number of co-integrated vectors in the model. The Johansen and Juselius method has been developed in part by the literature available in the field and reduced rank regression, and the co-integrating vector 'r' is defined by Johansen as the maximum Eigen-value and trace test or static, there is 'r' or more co-integrating vectors.

Johansen's method involves the estimation of the above equation by the maximum likelihood technique, and testing the hypothesis  $H_0: (\pi = \Psi\xi)$  of "r" co-integrating relationships, where r is the rank or the matrix  $\pi(0 < r < P)$ ,  $\Psi$  is the matrix of weights with which the variable enter co-integrating relationships and  $\xi$  is the matrix of co-integrating vectors. The null hypothesis of non-cointegration among variables is rejected when the estimated likelihood test statistic  $\phi_i = -n \sum_{i=r+1}^p \ln(1 - \hat{\lambda}_i)$  exceeds its critical value. Given estimates of the Eigen-value ( $\hat{\lambda}_i$ ) the Eigen-vector ( $\xi_i$ ) and the weights ( $\Psi_i$ ), we can find out whether or not the variables in the vector (RE) are co-integrated in one or more long-run relationships with the dependent variable.

This study investigates the influence of macroeconomic factors on renewable energy from two perspectives. One is to conduct the

modified Granger causality and Johansen cointegration tests to explore the influencing directions between different macroeconomic factors and renewable energy, respectively; the other is to compare the influencing magnitude of different economic factors on renewable energy, based on the vector error correction model (VECM) and variance decomposition approach.

In order to undertake the modified version of Granger causality for a VAR model with 3 lags ( $k=2$  and  $d_{max}=1$ ), we estimate the following system of equations:

$$\begin{bmatrix} RE \\ GDP \\ OR \end{bmatrix} = A_0 + A_1 \begin{bmatrix} RE \\ POP \\ OR \end{bmatrix} + A_2 \begin{bmatrix} RE \\ INDUS \\ OR \end{bmatrix} + A_3 \begin{bmatrix} RE \\ INF \\ OR \end{bmatrix} + A_4 \begin{bmatrix} RE \\ URBAN \\ OR \end{bmatrix} + A_5 \begin{bmatrix} RE \\ LSTOCK \\ OR \end{bmatrix} + A_6 \begin{bmatrix} RE \\ EXR \\ OR \end{bmatrix} + A_7 \begin{bmatrix} RE \\ FPI \\ OR \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \end{bmatrix} \quad (8)$$

Eq. (8) shows the modified version of Granger causality which has been calculated with the chi-square test rather than conventional Granger causality that has been considered with the  $F$ -statistics. The reasons to take on the chi-square statistics rather than  $F$ -statistics are that this study is based on multivariate cointegration rather than bivariate cointegration technique. Eq. (8) indicates the Granger causality where macroeconomic factors are independent variables which considered the impact on renewable energy.

From Eq. (8) we can test the hypothesis that Pakistan's economic indicators does not Granger cause renewable energy with the following hypothesis:

$$H_0^1 = a_{12}^1 = a_{12}^2 = 0$$

where  $a_{12}^i$  are the coefficients of the technology scale variable in the first equation of the system presented in Eq. (8). Besides, we can test the opposite causality from Pakistan's renewable energy to economic scale in the following hypothesis:

$$H_0^2 = a_{21}^1 = a_{21}^2 = 0$$

where  $a_{21}^i$  are the coefficients of the economic variables in the second equation of the system presented in Eq. (8). It should be noted that we incorporate the variable oil rent into Eq. (8) to avoid the omitted variable bias when we examine the Granger causality between economic indicators and renewable energy.

<sup>2</sup> If the series are integrated with the mixture of order of integration i.e.,  $I(0)$  and  $I(1)$ , it implies bonds testing approach which was proposed by Pesaran et al. [29].

### 3. Results and discussions

The present study conducts the Augmented Dickey–Fuller (ADF) unit root tests for all variables with regard to their stationary properties. The detailed results are shown in Table 2.

The results reveal that all variables in this study are non-stationary at their level, however, stationary at their first differences, therefore, we say that all variables are  $I(1)$  series at 1% level. After that, we take renewable energy (RE) as a dependent variable and each macroeconomic indicators and oil rent (OR) together as the independent variables, and then the Johansen cointegration

among them is tested according to Johansen [15]. From the results in Table 3, we find that economic indicators have at least one cointegration relationship with renewable energy at 5% level. Therefore, we may say that, for the most part, Pakistan's economic indicators have significant long-term equilibrium with renewable energy.

The study finds the short-run and long-run elasticities between the variables. Table 4 shows the short-run and long-run error correction results. The results show that in model A, there is a significant negative relationship between population growth and renewable energy in Pakistan, however, this result has been

**Table 2**

Augmented Dickey–Fuller (ADF) test on the levels and on the first difference of the variables (1975–2012).

| Variables | Level    |                    | First difference |                    | Decision  |
|-----------|----------|--------------------|------------------|--------------------|---|
|           | Constant | Constant and trend | Constant         | Constant and trend |   |
| RE        | −1.7913  | 0.0781             | −5.1015*         | −5.6994*           | Non-stationary at level but stationary at first difference i.e., $I(1)$ |
| OILR      | −1.1845  | −2.5160            | −7.9819*         | −7.8859*           | Non-stationary at level but stationary at first difference i.e., $I(1)$ |
| LSPI      | 5.7575   | −1.4397            | −3.310***        | −5.1030*           | Non-stationary at level but stationary at first difference i.e., $I(1)$ |
| INDUS     | −1.9560  | −2.425             | −4.629*          | −4.712*            | Non-stationary at level but stationary at first difference i.e., $I(1)$ |
| POP       | −1.1281  | −2.017             | −3.3855**        | −3.912**           | Non-stationary at level but stationary at first difference i.e., $I(1)$ |
| URBAN     | −0.6676  | −2.017             | −3.328***        | −3.412**           | Non-stationary at level but stationary at first difference i.e., $I(1)$ |
| INF       | 3.5873   | −0.2108            | −6.1662*         | −6.0836*           | Non-stationary at level but stationary at first difference i.e., $I(1)$ |
| EXR       | 0.117523 | −1.941             | −5.258*          | −5.174*            | Non-stationary at level but stationary at first difference i.e., $I(1)$ |
| FPI       | 1.3928   | −2.5613            | −4.6177*         | −4.7390*           | Non-stationary at level but stationary at first difference i.e., $I(1)$ |

Note: The null hypothesis is that the series is non-stationary, or contains a unit root. The rejection of the null hypothesis is based on MacKinnon [21] critical values i.e., at constant: −3.639, −2.951 and −2.614 are significant at 1%, 5% and 10% levels respectively. While at constant and trend: −4.252, −3.548 and −3.207 are significant at 1%, 5% and 10% levels respectively. The lag length are selected based on SIC criteria, this ranges from lag zero to lag four. \*, \*\* and \*\*\* indicates the significance level at 1%, 5% and 10% respectively.

**Table 3**

Results of Johansen cointegration tests.

|                                  | Hypothesized no. of CE (s) | Eigenvalue | Trace statistic | 5% Critical value | Prob.  |
|----------------------------------|----------------------------|------------|-----------------|-------------------|--------|
| Panel A: Series: POP, OPR, REE   | None <sup>a</sup>          | 0.558101   | 52.57064        | 35.19275          | 0.0003 |
|                                  | At most 1 <sup>a</sup>     | 0.284174   | 20.72038        | 20.26184          | 0.0432 |
|                                  | At most 2                  | 0.178788   | 7.681977        | 9.164546          | 0.0948 |
| Panel B: Series: EXR, OPR, REE   | None <sup>a</sup>          | 0.495024   | 46.88980        | 35.19275          | 0.0018 |
|                                  | At most 1                  | 0.294494   | 20.24326        | 20.26184          | 0.0503 |
|                                  | At most 2                  | 0.156519   | 6.638483        | 9.164546          | 0.1469 |
| Panel C: Series: INDUS, OPR, REE | None <sup>a</sup>          | 0.706045   | 66.96254        | 35.19275          | 0.0000 |
|                                  | At most 1                  | 0.262530   | 19.21378        | 20.26184          | 0.0692 |
|                                  | At most 2                  | 0.171494   | 7.337110        | 9.164546          | 0.1097 |
| Panel D: Series: INF, OPR, REE   | None <sup>a</sup>          | 0.468265   | 34.26638        | 29.79707          | 0.0143 |
|                                  | At most 1                  | 0.159097   | 9.633554        | 15.49471          | 0.3100 |
|                                  | At most 2                  | 0.071083   | 2.875697        | 3.841466          | 0.0899 |
| Panel E: Series: LSPI, OPR, REE  | None <sup>a</sup>          | 0.475904   | 37.47982        | 29.79707          | 0.0054 |
|                                  | At most 1                  | 0.257989   | 12.28272        | 15.49471          | 0.1439 |
|                                  | At most 2                  | 0.016414   | 0.645444        | 3.841466          | 0.4217 |
| Panel F: Series: URBAN, OPR, REE | None <sup>a</sup>          | 0.373115   | 39.59086        | 35.19275          | 0.0157 |
|                                  | At most 1 <sup>a</sup>     | 0.305294   | 21.37814        | 20.26184          | 0.0350 |
|                                  | At most 2                  | 0.167974   | 7.171756        | 9.164546          | 0.1176 |
| Panel G: Series: FPI, OPR, REE   | None <sup>a</sup>          | 0.312012   | 33.81098        | 24.27596          | 0.0024 |
|                                  | At most 1 <sup>a</sup>     | 0.270502   | 19.22562        | 12.32090          | 0.0030 |
|                                  | At most 2 <sup>a</sup>     | 0.162694   | 6.925051        | 4.129906          | 0.0101 |
| Panel H: Series: GDP, OPR, REE   | None <sup>a</sup>          | 0.578542   | 46.01170        | 29.79707          | 0.0003 |
|                                  | At most 1                  | 0.262961   | 12.31432        | 15.49471          | 0.1425 |
|                                  | At most 2                  | 0.010580   | 0.414837        | 3.841466          | 0.5195 |

Note: Dependent variable in each Johansen cointegration test is REE. <sup>a</sup> Rejection of the hypothesis at the 5% level.

**Table 4**  
Results of short and long-run error correction model.

| Variables   | Coefficients |
|---|--------------|
| <b>Model – A</b> $D \ln (RE)_t = \beta_0 + \beta_1 D \ln (POP) + \beta_2 D \ln (OILR) + \beta_3 D \ln (POP)_{t-1} + \beta_4 D \ln (OILR)_{t-1} + \mu$     |              |
| Constant  | –0.016*      |
| $D \ln (POP)_t$   | –0.386*      |
| $D \ln (OILR)_t$  | –0.016       |
| $D \ln (POP)_{t-1}$   | 0.281**      |
| $D \ln (OILR)_{t-1}$  | 0.007        |
| ECM   | 0.966*       |
| <b>Model – B</b> $D \ln (RE)_t = \beta_0 + \beta_1 D \ln (URBAN) + \beta_2 D \ln (OILR) + \beta_3 D \ln (URBAN)_{t-1} + \beta_4 D \ln (OILR)_{t-1} + \mu$ |              |
| Constant  | –0.015**     |
| $D \ln (URBAN)_t$   | 0.114        |
| $D \ln (OILR)_t$  | –0.015       |
| $D \ln (URBAN)_{t-1}$   | –0.104       |
| $D \ln (OILR)_{t-1}$  | 0.007        |
| ECM   | –0.674*      |
| <b>Model – C</b> $D \ln (RE)_t = \beta_0 + \beta_1 D \ln (IND) + \beta_2 D \ln (OILR) + \beta_3 D \ln (IND)_{t-1} + \beta_4 D \ln (OILR)_{t-1} + \mu$     |              |
| Constant  | –0.014       |
| $D \ln (IND)_t$   | –0.001       |
| $D \ln (OILR)_t$  | –0.018       |
| $D \ln (IND)_{t-1}$   | –0.001       |
| $D \ln (OILR)_{t-1}$  | 0.007        |
| ECM   | –0.695*      |
| <b>Model – D</b> $D \ln (RE)_t = \beta_0 + \beta_1 D \ln (EXR) + \beta_2 D \ln (OILR) + \beta_3 D \ln (EXR)_{t-1} + \beta_4 D \ln (OILR)_{t-1} + \mu$     |              |
| Constant  | –0.022*      |
| $D \ln (EXR)_t$   | –0.027       |
| $D \ln (OILR)_t$  | –0.008       |
| $D \ln (EXR)_{t-1}$   | 0.004*       |
| $D \ln (OILR)_{t-1}$  | 0.013        |
| ECM   | 0.599*       |
| <b>Model – E</b> $D \ln (RE)_t = \beta_0 + \beta_1 D \ln (INF) + \beta_2 D \ln (OILR) + \beta_3 D \ln (INF)_{t-1} + \beta_4 D \ln (OILR)_{t-1} + \mu$     |              |
| Constant  | –0.016*      |
| $D \ln (INF)_t$   | 0.005        |
| $D \ln (OILR)_t$  | –0.014       |
| $D \ln (INF)_{t-1}$   | –0.0006      |
| $D \ln (OILR)_{t-1}$  | 0.019***     |
| ECM   | 0.330***     |
| <b>Model – F</b> $D \ln (RE)_t = \beta_0 + \beta_1 D \ln (FPI) + \beta_2 D \ln (OILR) + \beta_3 D \ln (FPI)_{t-1} + \beta_4 D \ln (OILR)_{t-1} + \mu$     |              |
| Constant  | –0.008       |
| $D \ln (FPI)_t$   | –0.125       |
| $D \ln (OILR)_t$  | –0.013       |
| $D \ln (FPI)_{t-1}$   | –0.001       |
| $D \ln (OILR)_{t-1}$  | 0.004        |
| ECM   | –0.764*      |
| <b>Model – G</b> $D \ln (RE)_t = \beta_0 + \beta_1 D \ln (LSPI) + \beta_2 D \ln (OILR) + \beta_3 D \ln (LSPI)_{t-1} + \beta_4 D \ln (OILR)_{t-1} + \mu$   |              |
| Constant  | –0.010       |
| $D \ln (LSPI)_t$  | –0.054       |
| $D \ln (OILR)_t$  | –0.015       |
| $D \ln (LSPI)_{t-1}$  | –0.001       |
| $D \ln (OILR)_{t-1}$  | 0.006        |
| ECM   | –0.602**     |

Note: R-square range: minimum 0.121 to maximum 0.354. \*, \*\* and \*\*\* shows the 1%, 55% and 10% respectively.

disappeared in the long-run. While, in model D, exchange rate has a negative correlation with the renewable energy in Pakistan. In model E, oil rent has a significant positive relationship with the renewable energy as the coefficient value indicates 0.019% when one percent increases in oil rent. The overall results show the short-run dynamics and long-run convergence in the model, as in the models B and C, and model G indicates the value of error correction model is –0.674, –0.695 and –0.602 respectively. However, in the remaining models, this result has been appeared with the positive sign which shows the divergence in the model over a period of time.

Subsequently, we conduct the modified Granger causality tests by Toda and Yamamoto [42] for economic indicators and renewable energy. The variable oil rent is incorporated as an explanatory

variable to avoid the omitted variable bias. Results are shown in Table 5.

The causality test shows that there is a unidirectional causality running towards inflation to renewable energy, exchange rate, live stock production, and urbanization; GDP to exchange rate; food production to renewable energy; exchange rate to renewable energy; exchange rate to food production; oil rent to industrialization; industrialization to renewable energy; industrialization to inflation; urbanization to population; and renewable energy to oil rent. While, there is a bidirectional causality between exchange rate and live stock production in Pakistan. Finally, variance decomposition analysis was applied on the data set and it is found that GDP has a major contribution to increase renewable energy in Pakistan.

**Table 5**  
Causality test results among economic indicators and renewable energy.

| Null Hypothesis                                 | Chi-square statistic | Prob.   |
|---|----------------------|---------|
| RE does not Grange cause the changes in OPR     | 5.130027             | 0.0769  |
| OPR does not Granger cause the changes in RE    | 1.596347             | 0.4502  |
| FPI does not Grange cause the changes in RE     | 5.484072             | 0.0644  |
| REE does not Granger cause the changes in FPI   | 2.392640             | 0.3023  |
| EXR does not Grange cause the changes in REE    | 8.680982             | 0.0130  |
| REE does not Granger cause the changes in EXR   | 1.121366             | 0.5708  |
| EXR does not Grange cause the changes in FPI    | 8.010207             | 0.0182  |
| FPI does not Granger cause the changes in EXR   | 0.100097             | 0.9512  |
| EXR does not Grange cause the changes in LSPI   | 5.612979             | 0.0604  |
| LSPI does not Granger cause the changes in EXR  | 4.3812               | 0.0218  |
| OPR does not Grange cause the changes in INDUS  | 7.597764             | 0.0224  |
| INDUS does not Granger cause the changes in OPR | 4.813346             | 0.0900  |
| INDUS does not Grange cause the changes in REE  | 5.901169             | 0.0523  |
| REE does not Granger cause the changes in INDUS | 3.133233             | 0.0888  |
| INDUS does not Grange cause the changes in INF  | 11.45139             | 0.0033  |
| INF does not Granger cause the changes in INDUS | 1.560566             | 0.4583  |
| INF does not Grange cause the changes in REE    | 20.75661             | 0.0000  |
| REE does not Granger cause the changes in INF   | 3.602723             | 0.1651  |
| INF does not Grange cause the changes in EXR    | 30.05645             | 0.0000  |
| EXR does not Granger cause the changes in INF   | 1.313986             | 0.5184  |
| INF does not Grange cause the changes in LSPI   | 11.20088             | 0.0037  |
| LSPI does not Granger cause the changes in INF  | 0.337376             | 0.8448  |
| INF does not Grange cause the changes in URBAN  | 9.603817             | 0.0082  |
| URBAN does not Granger cause the changes in INF | 3.086636             | 0.2137  |
| URBAN does not Grange cause the changes in POP  | 14.01464             | 0.0009  |
| POP does not Granger cause the changes in URBAN | 0.586859             | 0.7457  |
| GDP does not Granger cause the changes in EXR   | 24.40569             | 0.0000  |
| EXR does not Granger cause the GDP              | 0.21256              | 0.82546 |

Note: The modified Granger causality test approach used in the table is provided by Toda and Yamamoto's [42]. And the causality tests between economic factors and renewable energy are based on the significance of chi-square statistics for Wald tests of VAR models.

Variance decomposition method is used for comparing the contribution of various economic indicators with the changes in the renewable energy in Pakistan. First, we take the renewable energy as the dependent variable, while economic indicators and oil rent together as independent variables, and conduct the Johansen cointegration test among these variables over a period of 36 years.

The results indicate that there exists statistically significant cointegration among Pakistan's economic indicators and renewable energy in Pakistan. Next, we apply the variance decomposition approach based on the vector error correction model (VECM) to explore the influence of economic variables on renewable energy, and compare their contribution difference. The results find that, among all economic factors, GDP exerts the largest influence, whose steady contribution level for renewable energy development approaches to 34.41%, while the influence of population is influencing with steady contribution level of 3.49%, urbanization is influencing at 4.97%, influence of inflation on renewable energy is 2.27%. The remaining variables like oil rent, exchange rate, food production index, live stock production index and industrialization influence renewable energy is 12.09%, 5.11%, 3.71%, 18.5%, 5.28% and 1.94% respectively.

#### 4. Conclusion and policy implications

In this study, we examine the long run relationship between renewable energy and economic factors along with oil rent over a period of 1975–2012 for Pakistan. The results reveal that there is a positive relationship between economic factors and renewable energy by intervening oil rent. The causality test depicts that there is a unidirectional causality running towards macroeconomic

factors to renewable energy in Pakistan. The results find that, among all economic factors, GDP exerts the largest influence i.e., 34.4% on renewable energy. Subsequently, live stock production contributed 18.5%, and oil rent contributed 12.09%. The least contribution is from industrialization to renewable energy i.e., 1.94% in Pakistan. Economic growth is heavily dependent upon renewable energy. While, policy makers have suggested that energy mix is only instrument for achieving success and reducing dependence upon oil. Oil volatility is severely affecting macro-economic factors of economy [8]. The only solution for long term is to separate the macroeconomic system from oil volatility by changing transforming new techniques for shaping renewable energy [31]. Mainstreaming of renewable energy and greater use of indigenous resources can help diversify Pakistan's energy mix and reduce the country's dependence on any single source, particularly imported fossil fuels, thereby mitigating against supply disruptions and price fluctuation risks [13]. According to Mirza et al. [23, p. 19]),

“Pakistan is currently facing a two-pronged crisis of threat to its Energy Security and an alarmingly low Human Development Index (HDI). Effective use of renewable energy can successfully address both these issues by improving the quality of life of the under-developed population, economic empowerment of the socially deprived and contribute to achieving the MDGs”.

Ozturk [25] suggested some worth noted policy implications in this regard i.e., Pakistan should have to install coal based power-houses, build nuclear energy plants, increase number of dams, increase natural gas stations, and publicize motivation programs for private sector who build renewable energy investment in a country. Pakistan should have to make some short-term plan, medium-term plan and long-term plan for sustainable future of the country. The short-term plan may consist of the following:

- Reduce the inflationary pressure especially food inflation and electricity prices and
- Increase the food production and livestock production in a country by using the subsidized and regular electricity to the industry. The cheaper and regular electricity would be generated through renewable sources available in the country.

The medium term plan should be the following:

- Manage exchange rate in terms of other countries where inexpensive electricity is acquired.

The long-term plan may focus on the following:

- Decrease the rural–urban migration, and it should be possible when Government should provide job opportunities in the rural areas of the country. Renewable energy would be an added advantage for providing cheap electricity to the rural industries.
- Decrease the population growth which exhausts the energy resources from the country.
- For rapid industrialization, Government should have to focus on renewable energy resources in a country especially, used solar energy, thermal, wind, biogas, geothermal etc.

Pakistan is the country where almost all types of renewable energy exists i.e., solar energy including Photovoltaic and thermal; wind, biodiesel production, biogas, geothermal etc. The two largest provinces of Pakistan i.e., Baluchistan and Sindh have a good opportunity to used solar energy, as approximately more than 2350 h per annum to 2900 h per annum sun shines existing

in these provinces. Government of Pakistan generating electricity through solar energy i.e., use of photovoltaic systems of electricity generation capacity is about 150 W per unit to 560 W per unit in a few rural areas, as around more than 43,000 villages of Pakistan have no access to electricity, therefore, Government of Pakistan have to focus on the available renewable energy sources in Pakistan to generate electricity. Subsequently, there are number of implications to produce cheap and regular electricity for Pakistan i.e.,

- Water, wind, solar system as well as coal could be used for cheap electricity.
- Geothermal energy may well in terms of low running costs over fossil fuel, as the costs for purchasing, transporting and clean-up plants is quite low.
- Due to the limited fossil fuel resource base, a large portion of the population in Pakistan lives in distant areas and is still waiting to be attached to the national electricity grid. Government of Pakistan should have to optimize the potential of wind power which is also still not so far been utilized significantly.

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